

Total Suspended Solid (TSS) Mapping of Wadaslintang Reservoir Using Landsat 8 OLI

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Abstract. Lakes, water reservoirs, and ponds are sources of fresh water that support the life of all living beings as well as human's social and economic activities. A common problem on reservoirs in Indonesia is the siltation due to the discharge of river materials into the reservoir. This process of sedimentation declines the function of the reservoir. Total Suspended Solid (TSS) can be used as the indicator of sediment in the reservoir, which usually consists of silt, fine sand and microorganisms. The high concentration of TSS in the water column can be used as the indication that the process of sedimentation in the reservoir is also high. This study aims to 1) map the spatial distribution of TSS and 2) estimate the TSS contained in Wadaslintang Reservoir using Landsat 8 OLI. The algorithm of TSS for Wadaslintang Reservoir was created based on the empirical relationship between field TSS data and reflectance values. Based on this research, it was found that the ratio of red and green band produced the best correlation with the TSS ($r = 0.533$). The resultant regression function of the regression analysis between ratio of red and green band and field TSS data was used to model the spatial distribution of the TSS on Wadaslintang Reservoir with standard error of 10.8 mg/l. The average TSS in the reservoir is estimated to be 22.61 mg/l.

1. Introduction

The availability of water resources is fundamental to support regional economic development. The limitation of water resources can impede and restrict the activities of development and economic prosperity of the people. Lake/reservoir water is used for various purposes, including the utilization of raw drinking water, irrigation water, power generators, flushing out, fisheries, and so on. The aforementioned functions of the lake water show just how important fresh water from reservoirs/Lakes to human life.

Wadaslintang is one of the reservoirs located in the province of Central Java, precisely located in Kecamatan Wadaslintang, Wonosobo Regency. This reservoir is of multifunctional use such as for raw water supply, power generation, irrigation and also tourism. With reservoirs have reached the age of 28 years, sedimentation is certainly have happened to this reservoir. One of the factors that indicate the occurrence of sediment in the reservoir is the presence of Total Suspended Solid (TSS), which is usually made up of silt and fine sand as well as microorganisms. The higher content of TSS in the water reservoir can indicate that the process of sedimentation in the reservoir is also high. Remote Sensing Technology is growing with the introduction of a wide range of satellite systems with a variety



of technologies, resolutions, and mission. Satellite remote sensing has been able to provide data and information on the natural resources of land and water regularly and periodically. This study aims to utilize remote sensing technology, in particular Landsat 8 OLI, to determine the spatial distribution of TSS and also to determine the amount of TSS contained in Wadaslintang Reservoir.

2. Methodology

This study is divided into three stages, namely the pre field survey, field survey and post field survey. Pre field survey including data collection, the correction of the image that will be used, and image processing to determine the sample locations. Field survey activity is the sampling of water in the reservoir Wadaslintang, for TSS levels calculation. Finally, the post-field stage is the laboratory analysis of TSS and analysis of TSS by using satellite imagery.

3. Analysis

3.1 Image Correction

Geometric correction was not performed in this study because the image used has been geometrically correct for the given scale, and thus no geometric correction is performed. Radiometric correction is an important process in digital satellite image processing and interpretation. In this research, Landsat 8 OLI DN was converted in Top-of-Atmospheric (TOA) reflectance using the following formula:

$$\rho_{\lambda'} = M_p Q_{cal} + A_p \quad (1)$$

$\rho_{\lambda'}$ = TOA reflectance of band λ

Q_{cal} = The value of the pixels (DN), as the band used

M_p = Constant rescaling (REFLECTANCE_MULT_BAND_x, where x is the band used)

A_p = Constant power (REFLECTANCE_ADD_BAND_x, where x is the band used)

The value of M_p and A_p are obtained from the image metadata

3.2 Preparation Of The Sample Point Field

To determine the location of TSS sample in Wadaslintang Reservoir, the water pixels of the reservoirs were classified based on their brightness levels using density slice technique, which is one of the simplest methods in categorizing or classifying objects, particularly for a single band analysis. The histogram of the Red band was used as the basis for the density slice, by identifying the major normal distribution curve of the histogram. The pixel value interval for the each resulting smaller normal distribution curve was used classify the image accordingly.

The interval of pixel value for each class is irregular, depending on the characteristic and variation of water clarity distribution across the scene. The of irregular intervals because of spectral reflection of material objects of the body of water on the interval for each class is as follows:

I : 0,053 - 0,055 (Red)

II : 0,055 - 0,057 (Green)

III : 0,057 - 0,059 (Blue)

IV : 0,059 - 0,061 (Yellow)

V : 0,061 - 0,064 (Cyan)

VI : 0,064 - 0,069 (Magenta)

VII : 0,069 - 0,075 (Maroon)

VIII : 0,075 - 0,087 (Sea Green)

The result of the density slice was used as the basis to determine location of the sample. Based on the eight density slice class, 64 sample locations were determined, where there are eight samples for each class. This eight samples per class was further divided into four samples for empirical modeling and four samples for accuracy assessment.

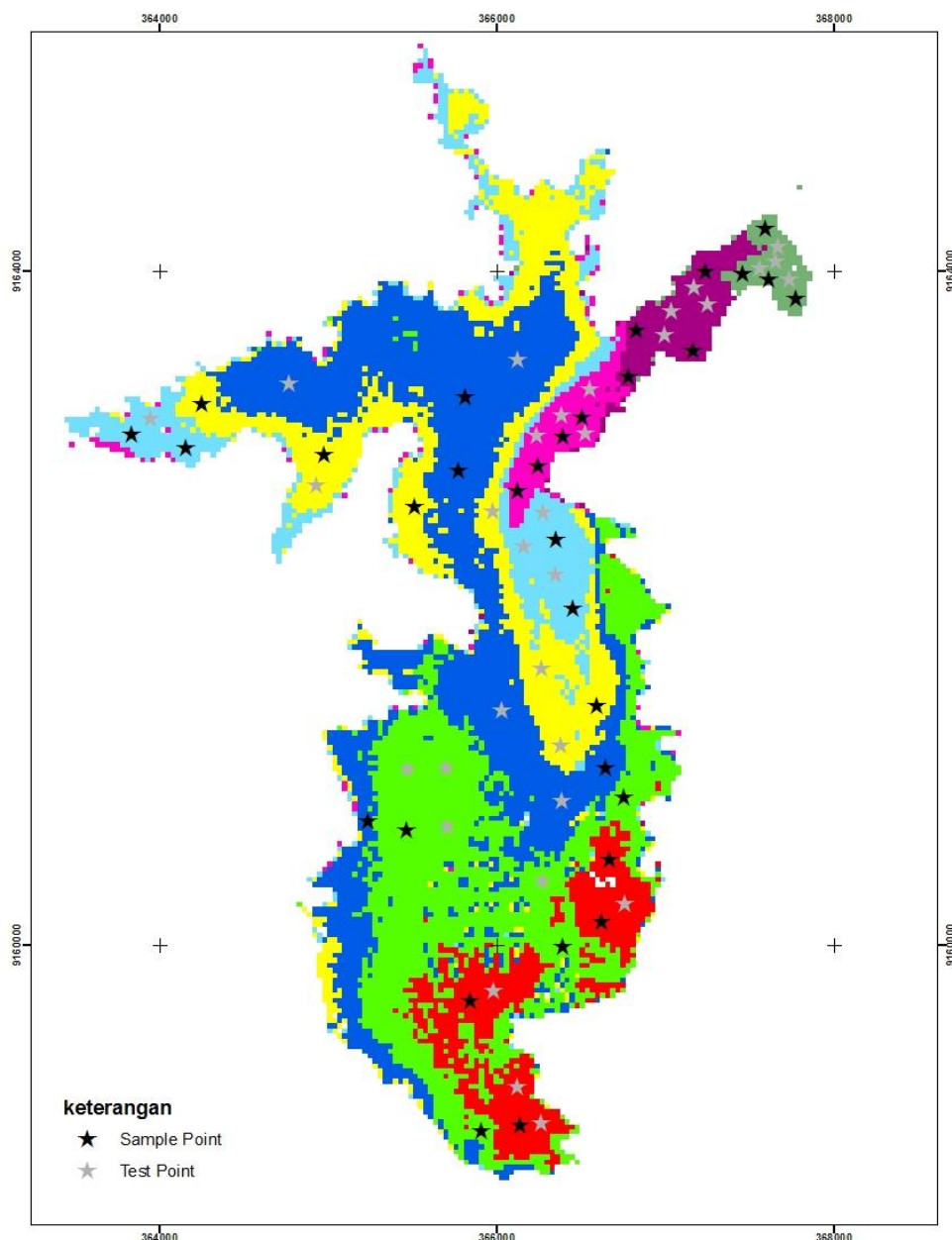


Figure 1. Location of samples for model and accuracy assessment

3.3 Field Survey

Field survey was performed on 6 August 2015. Motor boat was used as to visit each sample location. The actual location of the sample location was recorded using handheld GPS. The amount of water sample collected per site is 600 ml up to the depth of 30 cm. In total, 58 number of samples were collected during field survey.

3.4 TSS laboratory measurement

The TSS of the water samples was measured at the laboratory of Hydrology and Water Quality of the Faculty of Geography Universitas Gadjah Mada. Gravimetric method was used to measure the TSS (SNI-06-6989-3-2004).

Table 1. The result of laboratory measurement of TSS. Sample points were used to create an empirical model and test points were used to calculate the standard error of the estimated TSS.

No	Sample Code	TSS (mg/l)
1	Sample Point 1.1	13.8
2	Test Point 1.1	18.4
3	Sample Point 1.2	42.1
4	Test Point 1.2	33.6
5	Sample Point 1.3	12.3
6	Test Point 1.3	31.3
7	Sample Point 1.4	19.5
8	Sample Point 2.1	4.1
9	Test Point 2.1	37.5
10	Sample Point 2.2	37.7
11	Test Point 2.2	42.5
12	Sample Point 2.3	21.3
13	Test Point 2.3	15.1
14	Sample Point 2.4	38.8
15	Test Point 2.4	2.9
16	Sample Point 3.1	43.5
17	Test Point 3.1	20.8
18	Sample Point 3.2	11
19	Test Point 3.2	15.7
20	Sample Point 3.3	3.7
21	Test Point 3.3	7.4
22	Sample Point 3.4	7.2
23	Test Point 3.4	12.5
24	Sample Point 4.1	2.2
25	Test Point 4.1	4.6
26	Sample Point 4.2	2.7
27	Test Point 4.2	9.9
28	Sample Point 4.3	21.6
29	Test Point 4.3	8.3

No	Sample Code	TSS (mg/l)
30	Sample Point 4.4	10.3
31	Test Point 4.4	30.4
32	Sample Point 5.1	14.9
33	Test Point 5.1	15.4
34	Sample Point 5.2	11.7
35	Test Point 5.2	9.5
36	Sample Point 5.3	10.7
37	Test Point 5.3	11.7
38	Sample Point 5.4	10.5
39	Test Point 5.4	12.2
40	Sample Point 6.1	5.7
41	Test Point 6.1	23.8
42	Sample Point 6.2	29.9
43	Test Point 6.2	12.2
44	Sample Point 6.3	28.1
45	Test Point 6.3	1.6
46	Sample Point 6.4	17.5
47	Test Point 6.4	15.1
48	Sample Point 7.1	28.1
49	Test Point 7.1	32.8
50	Sample Point 7.2	11.7
51	Test Point 7.2	18.1
52	Sample Point 7.3	52.7
53	Test Point 7.3	42.8
54	Sample Point 7.4	23.9
55	Test Point 7.4	25.7
56	Sample Point 8.1	14.6
57	Test Point 8.1	94.1
58	Test point 8.3	15.3

3.5 TSS Data Processing Result

To obtain the empirical model of TSS using remote sensing image, on TSS, the pixel value of each TSS sample location was extracted. The results of this extraction was compared with the value of the field TSS data. Afterward, the Pearson correlation analysis was performed between field TSS and TOA reflectance value of Landsat 8 OLI bands i.e. 1 (Ultra blue), Band 2 (blue), (green) Band 3, Band 4 (red), Band 5 (Near infrared), Band 6 (SWIR), 7 Band (SWIR), Band 9 (Cirrus).

Table 2. The results of pixel values extraction from Landsat 8 OLI

No	X	Y	Ultra Blue	Blue	Green	Red	NIR	SWIR	SWIR	Cyrus
1.1	366015	9158935	0.0216	0.0223	0.0225	0.0165	0.0076	0.0047	0.0025	0.0014
1.2	366015	9158935	0.0216	0.0223	0.0225	0.0165	0.0076	0.0047	0.0025	0.0014
1.3	366585	9160195	0.0210	0.0214	0.0231	0.0158	0.0035	0.0042	0.0025	0.0011
1.4	366555	9160585	0.0211	0.0215	0.0232	0.0162	0.0013	0.0038	0.0025	0.0009
2.1	366375	9160015	0.0228	0.0232	0.0246	0.0175	0.0041	0.0042	0.0021	0.0015
2.2	366735	9160915	0.0221	0.0225	0.0245	0.0175	0.0048	0.0053	0.0033	0.0013
2.3	365475	9160765	0.0228	0.0233	0.025	0.0177	0.0021	0.0031	0.0019	0.0011
2.4	365925	9158935	0.0229	0.0229	0.0236	0.0172	0.0089	0.0056	0.0028	0.0012
3.1	366675	9161155	0.0223	0.0227	0.0261	0.0191	0.0035	0.0045	0.0029	0.0011
3.2	365745	9163225	0.0237	0.0247	0.0279	0.0190	0.0025	0.0033	0.0019	0.0014
3.3	365715	9162835	0.0236	0.0240	0.0282	0.0196	0.0026	0.0035	0.0023	0.0011
3.4	365325	9160765	0.0229	0.0232	0.0251	0.0179	0.0037	0.0034	0.0021	0.0012
4.1	366585	9161485	0.0233	0.0245	0.0281	0.0207	0.0037	0.0047	0.0031	0.0013
4.2	364275	9163225	0.0237	0.0245	0.0288	0.0202	0.0087	0.0056	0.0027	0.0014
4.3	364935	9162895	0.0238	0.0251	0.0282	0.0202	0.0077	0.0055	0.0029	0.0014
4.4	365535	9162625	0.0241	0.0246	0.0279	0.0204	0.005	0.0047	0.0026	0.0012
5.1	366435	9161995	0.0246	0.0260	0.0306	0.0222	0.0038	0.0043	0.0027	0.0012
5.2	366285	9162475	0.0241	0.0258	0.0303	0.0222	0.0036	0.0039	0.0023	0.0014
5.3	363825	9163045	0.0262	0.0264	0.0310	0.0223	0.0133	0.0071	0.0036	0.0016
5.4	364125	9162925	0.0260	0.0270	0.0317	0.0231	0.0145	0.0081	0.0039	0.0011
6.1	366135	9162745	0.0258	0.0272	0.0341	0.0254	0.0039	0.0042	0.0021	0.0014
6.2	366225	9162895	0.0262	0.0279	0.0355	0.0264	0.0067	0.0051	0.003	0.0014
6.3	366375	9163075	0.0256	0.0277	0.0351	0.0267	0.0065	0.0051	0.0029	0.0010
6.4	366465	9163165	0.0259	0.0281	0.0354	0.0267	0.0073	0.0055	0.0032	0.0012
7.1	366735	9163405	0.0265	0.0283	0.0364	0.0279	0.0086	0.0055	0.0033	0.0015
7.2	367125	9163585	0.0259	0.0285	0.0376	0.0293	0.0114	0.0062	0.0036	0.0011
7.3	367215	9163975	0.0277	0.0294	0.0394	0.0312	0.0128	0.0068	0.0039	0.0015
7.4	366825	9163645	0.0265	0.0286	0.0373	0.029	0.0088	0.0053	0.0029	0.0012
8.1	367515	9164005	0.0278	0.0304	0.0426	0.036	0.0130	0.0059	0.0033	0.0014
8.2	367575	9163945	0.0282	0.0317	0.0453	0.0398	0.0147	0.0063	0.0035	0.0011

These pixel values were used to build an empirical model of TSS using remote sensing data.

3.6 The Pearson Correlation Analysis

The correlation analysis was conducted to look at the relationship as well as the direction of the relationship of two or more variables. This was done in order to find spectral bands with significant relationship with the field TSS, which is necessary to perform regression analysis. Only spectral bands with significant correlation coefficient (r) that can be used as input in the regression analysis. The input pixel values for the empirical model are the value of a single band, band ratio, and band multiplication.

3.7 Regression Analysis

Regression analysis is used to predict the value of TSS using image pixel values. The scatter plot of the model with the highest R^2 is provided in Figure 2.

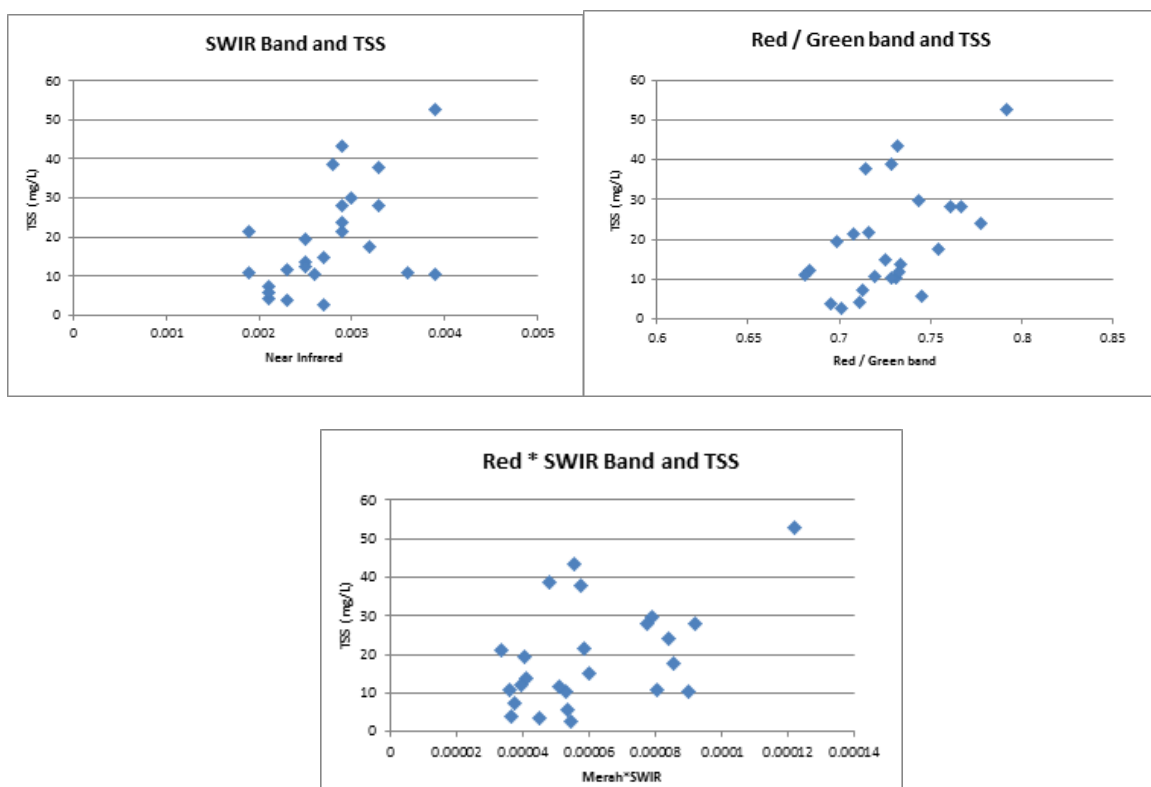


Figure 2. scatter plot showing the regression analysis of band 7, red/green band, and red*SWIR band with field TSS (informasi axis pakai bahasa inggris, lalu, garisnya dikeluarin Zi)

From the analysis, the ratio of red and green bands band produced the highest R^2 . The resultant regression function is $TSS = (255.78 * (\text{ratio red/green}) - 166.89)$.

3.8 Accuracy assessment

The resultant regression function of the best model was applied to Landsat 8 OLI image to obtain the spatial distribution of TSS in the Wadaslintang reservoir. To calculate the accuracy of the modeled TSS, the SE (Standard error of estimate) technique was used as follows:

$$SE = \sqrt{\frac{\sum (TSS \text{ Field} - TSS \text{ model})^2}{n - 2}}$$

Description:

SE (mg/L)

n = number of data

Table 3. The accuracy assessment of the TSS modeled from Red/Green band

No	X	Y	Reference TSS (mg/L)	Modeled TSS (mg/L)	(Reference TSS – Modeled TSS) ²
1	366105	9159205	18.4	16.457	3.776
2	365895	9159775	33.6	12.724	435.791
3	366645	9160345	31.3	8.888	502.283
4	365505	9161065	15.1	13.661	2.072
5	365685	9160675	2.9	18.121	231.674
6	366435	9160705	20.8	13.481	53.571
7	366105	9163525	15.7	10.476	27.293
8	364785	9163375	7.4	9.764	5.588
9	366045	9161395	12.5	18.362	34.368
10	366345	9161185	4.6	15.554	120.001
11	364935	9162745	9.9	13.038	9.847
12	365985	9162535	8.3	16.047	60.008
13	366225	9161665	30.4	18.572	139.890
14	366285	9162265	15.4	19.717	18.635
15	366255	9162565	9.5	24.532	225.975
16	363945	9163135	11.7	16.531	23.340
17	366225	9162385	12.2	20.026	61.249
18	366225	9163045	23.8	23.823	0.001
19	366495	9163075	12.2	28.793	275.317
20	366525	9163315	15.1	24.034	79.818
21	367005	9163615	32.8	37.078	18.303
22	367215	9163825	18.1	37.870	390.855
23	367155	9163945	42.8	37.217	31.167
24	367035	9163795	25.7	32.775	50.056
				Σ (Reference TSS – Modeled TSS)²	2800.877
				SE	10.803 mg/L

The results of the accuracy assessment produced standard error of 10.8 mg/l. That value is the representation of the average deviation of the modeled TSS. The median the median TSS modelling results is 20.3 mg/l. The value of SE is smaller than the average value of the modeled TSS.

4. Results & Discussion

Total TSS in Wadaslintang Reservoir was estimated from the TSS values of the modeling results. In calculating the total number of TSS, the number of pixel values and the content of TSS were used. The content of TSS is in mg / l, as measured by the TSS laboratory results. From the statistical results, the average TSS in the Wadaslintang reservoir on 2015 was 22.61 mg / l.

TSS mapping is intended to see the spatial distribution of TSS. The spatial distribution of TSS is the result of empirical modeling that was carried out before. Through spatial distribution map of TSS, the distribution of the magnitude of TSS in Wadaslintang Reservoir can be identified. The result also shows

that the area that contains the highest TSS on Wadaslintang reservoir is at the headwaters of the reservoir, which is located at the inlet of the main Wadaslintang reservoirs on the river Bedegolan. The TSS map also indicates that the content of TSS in that area is gradually increasing. The high TSS is observed in the field, where the area is very muddy compared to water in other areas of the reservoir.

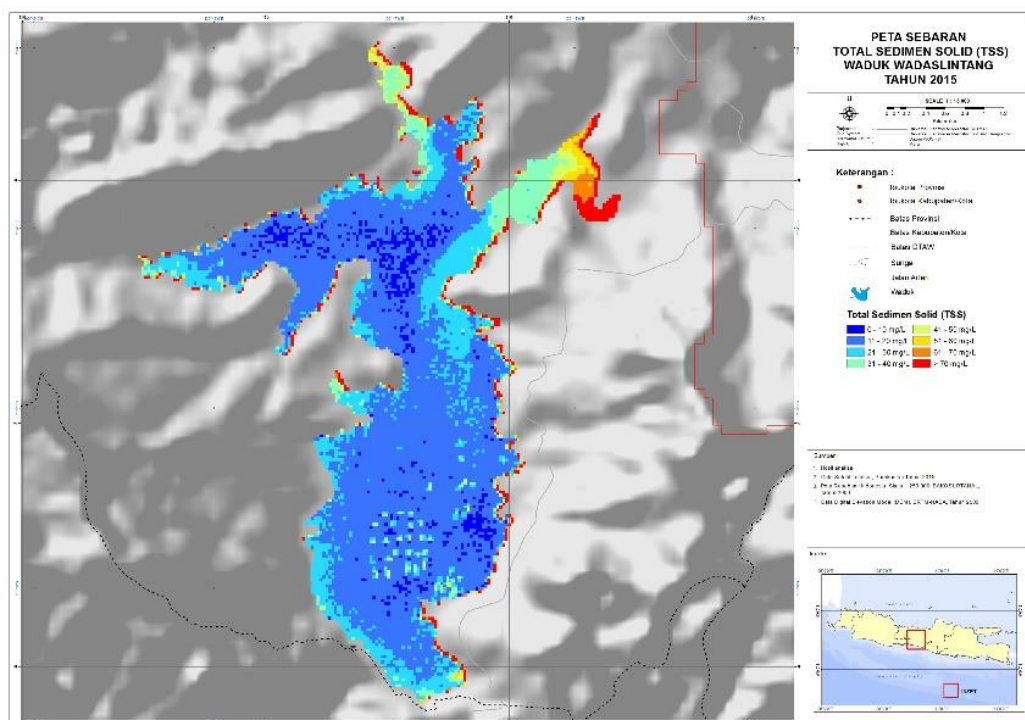


Figure 3. Total Suspended Solid Map in Wadaslintang Reservoir

Conclusion

The results of TSS mapping in the reservoir Wadaslintang using remote sensing image shows that the area with the highest content of TSS is in the region upstream of the dam, that is located at the inlet of the main Wadaslintang reservoirs on the river Bedegolan. TSS spatial distribution maps showed that the content of TSS in that area are gradually increasing, and accumulated in that area. The accuracy assessment on the accuracy of TSS results with independent field test showed that the value of the Standard Error is 10.8 mg / l. This value shows the average deviation of modeled TSS from the actual TSS value in the field. The average of modeled TSS is 20.3 mg / l.

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